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RESEARCH ON NATURAL HEARING AND THE DEVELOPMENT TOWARD ARTIFICIAL HEARING

by

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TITLE: RESEARCH ON NATURAL HEARING AND THE DEVELOPMENT TOWARD ARTIFICIAL HEARING

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The hearing system of the human race is a marvelous and delicate structure and is a functionally complete system for processing auditory information. The imitation of the function of natural human hearing in order to construct an artificial hearing system is a scientific and technological need which requires rapid development. This article, from the point of view of information processing and functional bionics, describes research on natural hearing and artificial hearing and the status of development toward it.

I. INTRODUCTION

Among all the relationships between the human race and the natural world, the auditory sense is one of the most important means by which information is obtained. In the process of the birth and development of human civilization, hearing is a key factor, which cannot be overlooked. Following along with the rapid development of science and technology, the human race not only gained a deeper and deeper understanding of the structure and functions of the natural hearing system. Moreover, there has been a deeper and deeper interest in research into and applications of artificial hearing systems. Looking from the angle of information processing and functional bionics, the natural hearing system and artificial hearing systems are both information processing systems which receive sound signals and, along with that, carry out synthetic processing of the information which is carried on them. It is obvious that research into natural hearing and the development toward artificial hearing are two aspects of the same problem. The two help each other in their completion and mutually promote each other.

II. THE INFORMATION TRANSMISSION ROUTES AND THE INFORMATION PROCESSING FUNCTIONS OF THE NATURAL HEARING SYSTEM

The process of hearing in human beings is a complicated one formed from the joint actions of various types of factors from such disciplines as physics, physiology, psychology and other similar studies. It is only when one carries out a deep and comprehensive consideration of the hearing system of human beings and the process of hearing from the point of view of such various disciplines as physics, physiology, and psychology, as well as other similar angles, that it is possible to understand the hearing mechanism in human beings from every aspect.

1. The Information Transmission Paths of the Natural Hearing System

The hearing system of human beings includes ears, the path between the ears and the brain, and three large sections of the brain. Its physiological structure is basically the same as that in mammals. Because of this, it is often helpful to use living animals to study the hearing system of human beings. However, the human hearing or auditory system is not only capable of sensing sound. It is also capable of making sense of the sounds of language. This is something which no mammal has any way of comparing to.

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(1) The Hearing Mechanism of the Human Ear

The human ear is a piece of signal receiving equipment which takes signals and gathers together in one body many types of functions such as filtering, amplifying, testing and measuring, analysis, energy transformation, modulus transformation, and other similar functions. Its several physiological reactions are governed by the laws of physics. Because of this, they go through the microscopic studies of physiology and the theoretical analysis of physics. As far as the hearing mechanism of the human ear is concerned, we already have a relatively precise understanding of it. Along with this, we have set up a preliminary physical model of hearing in the human ear as well as a numerical model.

In hearing, the function of the outer ear is primarily to gather sound. Sound signals pass through the spacial filtering of the ear space and resonance amplification in the ear canal. After that, they are turned into mechanical signals by the tympanic membrane. The function of the middle ear in hearing is primarily impedance matching. The middle ear realizes high efficiency transmission of signal energy on the basis of the lever actions of the chain of auditory bones and the piston action of the tympanic membrane, the auditory bone chain, and the oviform aperture. The primary function of the inner ear in hearing is signal analysis and modulus transfromation. The signal analysis function of the inner ear is completed by the mechanical action of the basal membrane inside the cochlea. In point of fact, the inner ear at the same time, and in a concurrent manner, has time period analysis and frequency analysis capabilities. This point of view has already been demonstrated by a considerable amount of research. The energy transformation and modulus transformation actions of the inner ear are completed in the spiral organ on the basal membrane. Davis makes use of tiny electrical terminals to measure the electrical potential on cochlea microphones and the operating electrical potential on the auditory nerves. The electrical potential of the microphones is transmitted into an electrical simulation of the sound signals. Making use of electro-acoustic transformation, it is possible, from the electric potentials of the microphones, to directly obtain the original sound signals. The operating electric potentials of the acoustic nerves produced by the contact from the electrical potentials of the microphones are, then, transformed into a form of code which appears as electrochemical pulses. Kiang and others have studied time duration information and frequency information, as well as strength information in terms of the formulae by which these codes are formed. Unfortunately, at the present time, people still do not have a deep understanding of the modulus transfromation mechanisms of the inner ear, and they are still unable, from the operating electrical potentials of the acoustic nerves, to reproduce the original sound signals transmitted.

(2) Transmission of Information from the Ear to the Brain

The routes of information between the ear and the brain are through approximately 30,000 hearing fiber structures in the auditory nerves. These nerve fibers possess various differing response peculiarities and frequency characteristics. There is no single nerve fiber that is capable of going the whole way. On the contrary, messages get through by sudden contacts making the nerve fibers connect with one another. Moller drew out a schematic diagram for the principal upward hearing paths. Among these paths are included the cochleal core, the upper oliva or olivary body, the exterior ansa or lemniscus, the colliculi inferioris laminal quadrigeminal, and the lateral corporis geniculati, as well as several other similar key way stations. A good number of people have carried out investigations into the structure, properties and functions of these way stations or intermediate transmission points, and they have arrived at a number of useful conclusions as well as raising a number of possible hypotheses. The more evident point of view is that the intermediate transmission points or relay stations on the auditory path are a number of groups of special cells, that there is a division of labor among the neurons in the cell groups, that some of them only respond to noise, and that some of them only respond to pure sound. These relay stations and the hearing fibers together realized or actualized the upward path of information transmission and pre-processing.

There is already evidence which clearly demonstrates that, besides the upward information path from the ear to the brain, there is also a downward information path from the brain to the ear. The downward path is made up of approximately 500 nerve fibers. Their function is to control the producing and inhibiting actions of hair cells or relay stations on upward signals.

(3) Auditory Mechanisms of the Cerebrum

The cerebrum is the core of all the activities of life for the human race. It is the overall processing center for various types of sensory information. The processing of auditory information is only one function of the cerebrum. From the cochlea to the colliculi 11
inferioris laminal quadrigeminal, the pre-processing or pre-treatment of auditory information is already completed. All the various factors relating to the sound signals being transmitted, such as duration, frequency, strength, and direction, have already been basically analyzed and clarified. The final process of sound identification is finished in the auditory area of the cerebral cortex. Due to the fact that the experimental technology is difficuit, at the present time, it is still not possible to clearly delineate the location and scope of the hearing zone. It is also not possible to adequately understand

the sound identification functions of the neurons of the auditory zone or area. Through experimentation, Wernicke has demonstrated that the cerebral cortex of the human race not only possesses the general hearing area that is universally seen in mammals, but has a language hearing area which is possessed peculiarly by human beings. Between the two hemispheres of the cerebrum, there is the corpus colosum, which is composed of 200 million nerve fiber structures and connects the two sides, allowing a unified coordination of spacial reactions. There are people who have done studies of the division of labor in hearing between the two hemispheres of the cerebrum. These would indicate that the primary hemisphere is in charge of hearing language, and the secondary hemisphere takes charge of hearing music. 97% of people have their left hemisphere as dominant and their right hemisphere as secondary. Moreover, the left brain primarily receives auditory information sent in from the right ear, and the right brain primarily receives auditory information sent in from the left ear. As a result of this, one sees the appearance of a superiority of the right ear in hearing language and a superiority of the left ear in hearing music.

2. Information Processing Functions in Natural Hearing Systems

The process of hearing in human beings is the result of a cooperative operating of the first signal system which is possessed by all mammals and the second signal system which is possessed peculiarly by the human race. The core of the hearing process is the comprehensive or general processing of auditory information by the cerebrum. This is a complicated and subtle psychological activity associated with the setting up of relationships between external stimulations and internal reactions. In the hearing process, and, in particular, in the process of hearing language, it cannot be separated from such general or comprehensive operations of memory and cognative abilities as recall and knowledge, association and inference, analysis and synthesis, comparison and discrimination, and other similar functions.

(1) The Process of Hearing Language

The psychological activities of hearing language can be generally divided into the three steps of language learning, language apprehension, and language understanding or comprehension. Language learning (the acquisition of the language) is a process in which individual human beings obtain language knowledge and acquire listening and speaking functions. It is a step which must be gone through. The process of language apprehension (language recognition) is the step in which, after going through language study, people possess the ability to hear the language and make out correctly and without error such language components as syllables and vocabulary items. Language comprehension (language grasp) is a process in which, on the foundation of language apprehension, one draws on the language knowledge he already has, and, along with it, takes the step to go through thought processes with the vocabulary, phrases, and other similar elements among the language components so as to correctly grasp expressed meanings. In actual fact, these steps cannot be distinctly separated. If language learning is separated from language apprehension and language comprehension, then, there is no way to carry out an accumulation of language knowledge. If language apprehension is separated from language comprehension, then, it is difficult to accurately and effectively make out the sounds of the language. At the present time, there is still not a single point of view concerning the mechanism for acquiring languages. There are those who have brought up the fact that the process of hearing language is not a passive process but is an active process, that is, the hearer, beforehand, forms the idea of the sounds of the language in his mind, and, along with this, organizes the spoken grammar rules. After getting the idea of the language, the sounds of the language and the spoken grammar are then automatically eliminated from his memory.

(2) The General Process of Hearing

In human beings, the process of hearing sounds which are not language is the same as that for other mammalian animals. This is, once again, a product of the operation of the first signal system. Its real nature is a conditioned reflex in the hearing system of human beings to sound stimulations. The difference from the hearing process in other mammalian animals is that in the process of human beings hearing sounds which are not language, besides the functioning of the first signal system, one also has the participation of the second signal system. On the foundation of all the conditioned reflexes, it also includes the recognition and understanding of the peculiar nature of the sound source and the properties of the sound waves. As a result of this, when people hear the sound of wind and rain, they are not only able to differentiate between the sound of wind, the sound of rain, and the sound of reading a book. Moreover, they are able to connect the two concepts of wind and rain together, even to the point where it is possible to figure the strength of the wind and the amount of the rainfall. Speaking in terms of this point of the joint operation of the two signal systems, the process of human beings hearing sounds which are not language and the process of hearing language are in line with each other in the aspects of information processing functions.

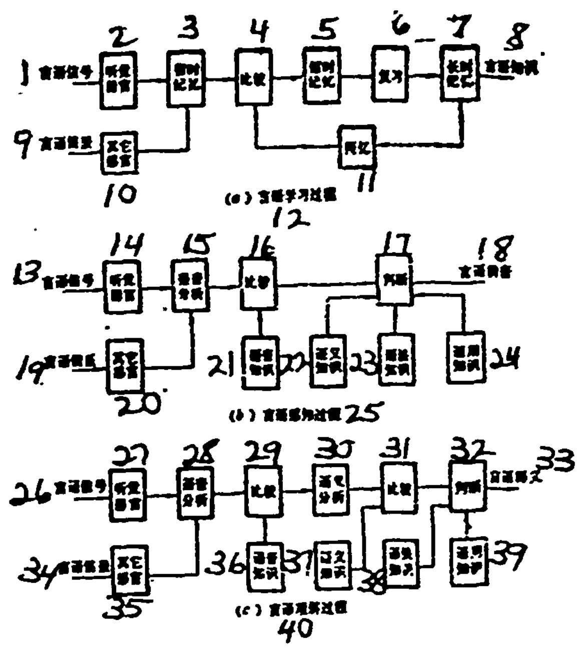

Fig.1 A Schematic Diagram of the Process of the Natural Hearing System Listening to Language (1) Spoken Language Signals (2) Auditory Organs (3) Temporary Memory (4) Comparison (5) Short Term Memory (6) Review (7) Long Term Memory (8) Knowledge of the Spoken Language (9) General View of the Spoken Language (10) Other Sense Organs (11) Recall (12) (a) The Process of Learning Spoken Language (13) Spoken Language Signals (14) Auditory Organs (15) Analysis of the Sounds of the Language (16) Comparison (17) Discrimination (18) Making Out the Language (19) General View of the Spoken Language (20) Other Sense Organs (21) Language Knowledge (22) Knowledge of the Meaning of the Language (23) Knowledge of Spoken Grammar (24) Knowledge of Spoken Usage (25) (b) The Process of Apprehending Spoken Language (26) Spoken Language Signals (27) Auditory Organs (28) Analysis of the Sounds of the Language (29) Comparison (30) Analysis of the Meaning of the Language (31) Comparison (32) Discrimination (33) Interpretation of the Spoken Language (34) General View of the Spoken Language (35) Other Sense Organs (36) Knowledge of the Sounds of the Language (37) Knowledge of the Meaning of the Language (38) Knowledge of the Grammar of the Spoken Language (39) Knowledge of the Usage of the Spoken Language (40) (c) The Process of Comprehending Spoken Language

III. ARTIFICIAL BIONIC SYSTEMS FOR GENERAL HEARING FUNCTIONS AND THE FUNCITON OF LISTENING TO SPOKEN LANGUAGE

Natural human language is one type of most convenient form for exchanging information between human beings as well as between men and machines. Because of this, making machines possess a similar type of hearing function and function for pronouncing words is an objective which people are striving for diligently. The development of science and technology in this era has offered the necessary conditions for the development of artificial hearing systems. Requirements for the production and life of human beings present an excellent future prospect for applications of artificial hearing systems. At the present time, not only are the properties of artificial bionic systems being perfected everyday for general hearing functions. Moreover, artificial bionic systems for the function of listening to spoken language are also striding toward the stage of practical use.

1. Artificial Bionic Functions for General Hearing

The most successful actual examples of artificial bionic functions for hearing non-language are the various types of sonar systems. The sound gathering, energy tranformation, amplification, filtering, encoding, waveform analysis, frequency spectrum analysis, and other various similar functions of hearing associated with human ears and ear-brain pathways are respectively taken charge of by sonar's acoustic-electrical energy transformer devices, amplifiers, filtration devices, modulus transformation devices, and pre-processing equipment. Moreover, the general or comprehensive information processing functions of the human brain are taken over by various models of computer. The function of people making use of both their ears to precisely determine the direction of sources of sound is the fundamental basis for the basic matrix design of sonar energy transformer devices. The guidance systems of acoustically guided torpedos are nothing more than imitations of human hearing with its sense of direction and the subsequent designing of an artificial hearing system. Modern sonar systems are not only capable of 12
precisely determining the direction of targets. Moreover, they are capable of making use of target radiated sound and reflected sound to identify target type and to grasp the operational status of the target. Making use of mechanical equipment to make automatic

malfunction diagnoses from the vibration noise of mechanical equipment during operation is, in point of fact, also a type of application of artificial hearing systems.

2. Artificial Bionic Functions for Hearing Spoken Language

The spoken language signals of human beings are a type of special acoustic signal. The sounds of language are a form of expressing language. The meaning of language is the expressed content of spoken language. The form and content of spoken language is also influenced by the constraints of spoken grammar and usage. When people listen to languge, they are not only capable of distinguishing the sounds of the language. Moreover, it is possible for them to understand the meaning of the language. It follows from this that it is also possible, on the basis of the mood of the information in the signals of the spoken language, to make judgments about the person doing the speaking. The recognition or distinguishing of language, the understanding or comprehension of it, and the recognition or distinguishing of the persons doing the talking are the three basic types of model for artificial systems to hear language.

(1) Systems to Recognize Language

The core problems of the apprehension of language and the comprehension of language are types of recognition. In order to make description easy, one normally takes the types of recognition and divides them into the two large catagories of statistical type recognition and structural type recognition. In point of fact, the human brain carries out methods for type or holotype recognition which should be two types of organic synthesis or binding. Moreover, they cannot be separated from the functions of knowing. As a result of this, there have been people who have brought up hypotheses relating to the recognition of syntactical language meaning types and the recognition or distinguishing of basic types of knowing. However, at the present time, the principal broad applications are statistical types of recognition.

The object of language recognition is vocabulary. However, whether the basic units of language recognition are syllables or phonemes is still not definitely decided. The structure of language recognition systems generally includes several links such as analysis of the sounds of the language, extraction of characteristics, matching of types or holotypes, recognition decisions, and other similar processes. The characteristic parameters used in the recognition of language are very numerous. They include such items as basic frequency, resonance peaks, short term energy, spectrum envelope, rate exceeding zero, linear prediction coefficients, component relation systems, acoustic path section functions, Fourier coefficients, inverse spectra, polar errors, and other similar factors. It is possible, on the basis of the actual situation, to add options. This is relatively similar to the process of natural hearing in human beings, and artificial hearing systems also need to go through practice and learning.

Normally, on the basis of recognition functions, language recognition systems are divided into those that are designed to handle one particular person and those that are designed to handle many people, systems that recognize small amounts of vocabulary and systems that recognize large amounts of vocabulary, and systems which recognize singly uttered words and phrases and systems which recognize continuously uttered words and phrases. It is relatively easy to realize language recognition systems which are aimed at single persons, small amounts of vocabulary, and singly uttered words and phrases. Under conditions in which there is adequate cooperation between humans and machines, it is possible to reach quite high rates of recognition. At the present time, in the international marketplace, there are already many types of commercial products answering the demand. It is relatively complicated to realize language recognition systems which are aimed at multiple persons, large amounts of vocabulary, and continuously uttered words and phrases. Their recognition rates are not easy to raise, and there will still be quite a few difficulties in putting these into practical use. At the present time, there are already people who have presented many types of improved designs for such things as multiple holotype matching, characteristic parameter regression or unitization, single word or phrase space separation, statistical recognition, and the mutual linking together of structures which have been recognized, as well as other similar projects.

(2) Systems for Comprehending Language

The understanding of language is a high level step in the hearing of language. The object of language recognition is vocabulary words and phrases. However, the object of understanding language is sentences. Sentences are composed of vocabulary. However, sentences are not simple piles of vocabulary items. They are organic linkings

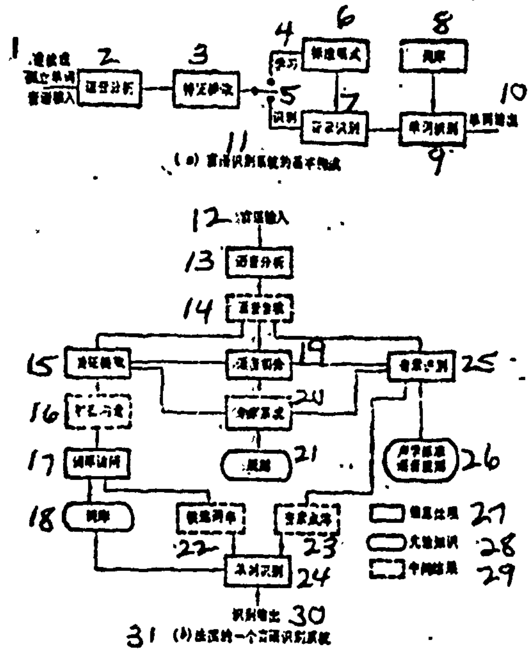

Fig.2 The Basic Structure of Systems for Recognizing Language and Actual Example of These Systems (1) Language Composed of Continuous Independent Words Is Fed In (Text Unclear) (2) Analysis of the Sounds of the Language (3) Extraction of Characteristics (4) Learning (5) Recognition (6) Target Holotypes (7) Recognition of the Sounds of the Language (Text Unclear) (8) Vocabulary Storage (Text Unclear) (9) Recognition of Individual Vocabulary Items (10) Output of Individual Vocabulary items (11) (a) The Basic Structure of Systems for Recognizing Language (12) Input of Language (13) Analysis of the Sounds of the Language (14) Parameters for the Sounds of the Language (15) Characteristic Extraction (16) Characteristic Vectors (Text Unclear) (17) Visit Vocabulary Storage (18) Vocabulary Storage (19) Division of the Sounds of the Language (Text Unclear) (20) Expert System (21) Rules (Text Unclear) (22) Select Vocabulary String (Text Unclear) (23) Sound Element Dot Matrix (Text Unclear) (24) Recognition of the Individual Vocabulary Item (25) Recognition of Sound Elements (Text Unclear) (26) Standard Acoustic Rules for Language Sounds (27) Information Processing (28) <u>A priori</u> Knowledge (29) Intermediate Results (30) Recognition Output (31) (b) A French Language Recognition System

of vocabulary items. The actual form of this type of linking is determined by the rules of grammar, the semantic content or meaning of the language, and the usage environment. The structures of systems for comprehending language generally include the key links of analysis of the sounds of the language and recognition of the sounds of the language, the matching of words and phrases and the selection of words and phrases, the analysis of the semantics or meaning of the language and the composing of sentences, as well as other similar steps. The recognition of language is the initial level in the steps of comprehending language. The results of the recognition of language directly influence the results of the comprehension of language. A perfect language comprehension system should include a relatively perfected knowledge storage facility. It should possess such cognative functions as association and deduction, as well as other similar capabilities, and, along with that, a means capable of automatically correcting errors and selecting relatively ideal expressions.

The comprehension of language is the foundation for oral dialogue between humans and machines. It is one of the necessary conditions for making robots into intelligent beings. In oral translation, orally dictated typing, oral control, automated management, and automated command, as well as other similar aspects, everyone is earnestly waiting for the improvement and perfecting of the capabilities of language comprehension systems. However, due to the high degree of complexity of natural human languages, one sees the existence of many difficulties in the realization of language comprehension systems. The dialogue typewriter test manufactured by the U.S. IBM Company and the dictation typewriter test manufactured by the Applied Intelligence Company are both real time machines for recording dictated sentences. The difference between the two lies in the fact that the dialogue typewr[illegible]er is a large model statistical recognition system which carries out sifting operations on words and phrases on the basis of the relationships between the words in, before, and after sentences. On the other hand, the dictation typewriter, by contrast is a composite system bringing together various types of recognition techniques in comprehensive operations.

(3) Systems for Recognition of the Person Doing the Talking

The physical form of language is signals in the sounds of the language. The information inherent in the language, by contrast, includes both the two aspects of the semantic information and the mood of the information. The sex of the speaker, his age, occupation, career history, education and training, habits, feelings, and even the condition of his or her health are all capable of being reflected in the language. When different people speak the same sentence, the semantic content or meaning is completely the same. However, the detailed flavor is very, very different. What is involved in the recognition of language and the comprehension of language is the common characteristics of language. However, by contrast, what is involved in the recognition of the person doing the speaking is the unique, individual characteristics of language.

The distinguishing of the person doing the speaking normally includes the two types of content found in the recognition of the person doing the talking and the differentiation of the person doing the talking. The task of differentiating the person doing the speaking is one of taking a large number of unknown language sounds and a registered language sound and comparing them to each other deciding which of the unknown sounds is the same as the registered sound. The task of recognizing the person doing the speaking is one of taking one unknown language sound and comparing it to many 13
registered sounds in order to decide which one of the registered sounds the unknown language sound is like. Systems which recognize the person doing the speaking are also capable of being divided up on the basis of whether or not the content of the speech is based on a written text or is independent of any written text. Speech recognition systems which depend on written texts and systems which recognize the speech of a particular person are similar. They are relatively easy to realize, and it is possible to reach relatively high rates of recognition. Systems which recognize speech independent of written texts and language recognition systems aimed at many different people resemble each other in that they are relatively difficult to realize and it is not easy to raise recognition rates.

The structure of systems for recognizing the person doing the speaking and language recognition systems are basically the same. Due to the fact that inherited characteristics of individual speakers

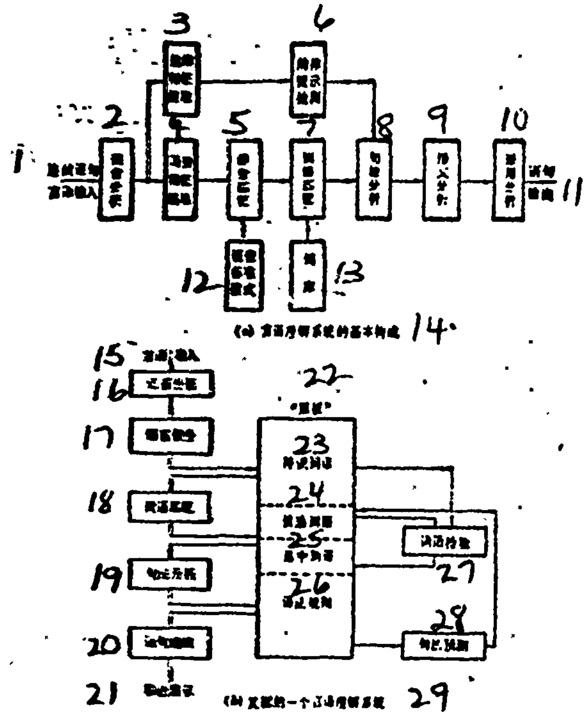

Fig.3 The Basic Structure of Systems to Comprehend Language and Example of an Actual System (1) Input of Language in Continuously **Connected Sentences (Unclear)** (2) Analysis of Spoken Language **(Unclear) (3) Extraction of Characteristics of Phonetic Patterns (Unclear) (4) Extraction of the Characteristics of the Sounds of the Language (5) Matching of the Sounds of the Language** (Unclear) (6) **Display, Checks, and Measurements** of Phonetic Patterns (Unclear) (7) **Language Matching (Unclear) (8)** Analysis of Syntax (9) Analysis of **Semantics (10) Analysis of Usage** (11) Sentence Output (12) **Standard Holotypes for the Sounds of the Language** (13) Vocabulary **Storage (Unclear) (14) (a)** Basic Structure of Systems for Comprehending Language **(15)** Language Input (16) Analysis of the Sounds of the Langauge (17) Separation of the Sounds of the Language (18) Matching of Words and Phrases (19) Analysis of Syntax (20) **Sentence Organization (21) Output Display** (22) "Blackboard" **(Unclear) (23) Words and Phrases** Waiting to Be Recognized (Unclear) (24) (Unclear) Words and Phrases (25) Selected Words and Phrases (Unclear) (26) Grammar Rules (Unclear) (27) Experimental Testing of Words and Phrases (Unclear) (28) Syntactical Prediction (29) (b) A U.S. System for Comprehending Language

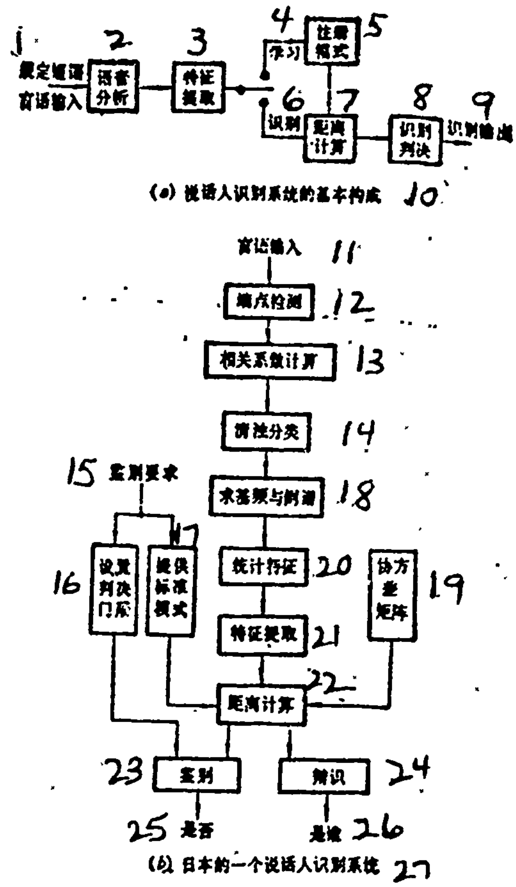

Fig.4 Basic Structure of Systems for Recognizing Speakers and an Actual Example of a System (1) Regulated Phrasal Language Input (2) Analysis of the Sounds of the Language (3) Extraction of Characteristics (4) Learning (5) Registered Holotypes (6) Recognition (7) Distance Calculations (8) Recognition Decision (9) Recognition Output (10) (a) Basic Structure of a System for Recognizing Speakers (11) Language Input (12) Terminal Checks (13) Correlation Coefficient Calculations (14) Clarity Classification (15) Differentiation Requirements (16) Install Decision Gate Limits (17) Supply Standard Holotypes (18) Solve for Basic Frequency and Inverse Spectrum (19) Covariant Matrix (20) Statistical Characteristics (21) Characteristic Extraction (22) Distance Calculations (23) Differentiation (24) Recognition (25) Yes/No (26) Who is it? (27) (b) A Japanese System for Recognizing Speakers

(such as the physiological structure of the speech canal and the vocal cords) which manifest themselves along with acquired characteristics (such as tonal patterns and intonation, as well as other similar habits of pronunciation) are always very difficult to separate, as a result, normally, one considers them together. In order to reduce the influence of changes over time in characteristic parameters on recognition system properties, there are people considering opting for balanced processing of frequency spectra, long term averaging of data, the updating of standard holotypes, and other similar measures.

IV. FUTURE PROSPECTS FOR THE STUDY OF NATURAL HEARING AND THE DEVELOPMENT OF ARTIFICIAL HEARING

Research into natural hearing has already obtained a great many results. However, looking from the point of view of the need to treat medical problems in the human body and the need for artificial hearing, there are still quite a few difficult riddles to solve. The approach to artificial hearing has undergone a very great deal of development. However, looking at it from the point of view of the need for artificial bionics and practical applications, there are still quite a number of technological difficulties. One must think that the test manufacture of artificial hearing systems has undergone even greater development. On the the one hand, this was determined by an even deeper understanding of information processing in the natural hearing systems of human beings. On the other hand, it was determined by an even greater development and utilization of hardware and software resources for the study of artificial hearing.

1. Research Into the Theory of Natural Hearing Functions

As far as the process of people making use of nat l language to exchange information between themselves is concerned, it includes the two aspects of talking and listening. With regard to the pronouncing organs of human beings, there already exist relatively complete physical and numerical models for the section from the glottis to the nose and mouth. However, it has yet to include within it the cognative functions of the speech center in the cerebrum. Moreover, as far as the hearing organs of human beings are concerned, we have yet to have unified physical and numerical models of the section of them from the ears to the cochlea. This goes even more without saying if one considers at the same time the requirement for the cognative functions of the hearing center in the cerebrum. One type of ideal scientific model should provide one type of normal or proper, economical, elegant description of the natural system. This type of model should be a type of simplified display. It follows from this that it should make researchers able to concentrate their prime attention on the key attributes of the system. As far as the setting up of one complete model for the hearing system is concerned, it will be a very, very great help in the understanding of this complicated and sensitive natural system.

The peripheral nerves between the cochlea and the cerebrum (the ear-brain path of hearing) are a high efficiency communications network which has horizontal and vertical interconnections and complicated functions. The relay stations within the communications network not only transmit information up and down. Moreover, they process the information they handle on the spot. They are also capable of making the hearing system and other sensory systems in
human beings (such as sight, smell, and so on) develop lateral or 14
transverse connections. As far as a more advanced understanding of this network's structure is concerned--in particular, the setting up of accurate, complete physical and numerical or mathematical models--it will undoubtedly be a very great help to the design of software and hardware for artificial hearing systems.

The human brain possesses special cognative activities and memory capabilities. In analyzing questions, it is capable of far-ranging associations of thought and rational deductions. During its handling of problems, it is capable of responses to random emergencies and accurate determination of courses of action. The human mind carries out comprehensive information processing capabilities and methods. It is of an ideal state to which any artificial system can aspire but never reach. Getting a clear picture of the physiological, physical, and psychological mechanisms which the cerebrum uses to carry out cognition and memory and the setting up of a complete model of the comprehensive information processing of the human brain are conditions which must be satisfied before it will be possible to test manufacture a computer with superintelligent properties. The recognition of language, the comprehension of language, the recognition of speakers, and other similar achievements in the further development and perfection of artificial hearing systems all rely on deep research into the cognitive functions and the memory functions of the cerebrum.

2. The Development of Resources Associated With Artificial Hearing Systems

As far as the rapid development of microelectronic industrial techniques and computer technology is concerned, it has prepared an increasingly solid material base for the development of artificial hearing systems. With regard to the continuous perfecting of holotype recognition theory and the theory of intelligence simulation, it has furnished an ever firmer logical basis for the improvement of artificial hearing systems. In the process of the test manufacture of artificial hearing systems, as far as accumulated knowledge and exerience are concerned, they are also propelling the continuous forward development of this work.

Looking from the point of view of computational linguistics, during the process of subjective and objective social intercourse, it is taken as a language communication process associated with the mutual cooperation of a speaker and a listener on the foundation of the knowledge which both sides possess If the two lack a common foundation of knowledge, there is then no way to arrive at the goal of cooperative communication. Speaking from the perspective of applications of artificial hearing systems, the subjective side (the speaker) is a person, but the objective side (the listener) is a machine. If one makes people and machines capable, on the basis of a foundation of common knowledge, to cooperate in communication, there are two paths that offer options: one is that the person accomodates himself to the machine, that is, he takes his pronunciation, choice of vocabulary, sentence construction, and other similar factors and strictly limits all of them to within the scope of knowledge the machine is capable of using. The second is the machine suiting itself to the human, taking the sounds that it hears, its understanding of vocabulary, its translations of sentences, and other similar factors, and, as much as possible, approaches the range of knowledge that is used by the human. How one can take abundant knowledge and carry out high efficiency storage and agile operations is a question which is really awaiting an answer.

Recognition systems for use with single persons, small amounts of vocabulary, and words and phrases presented singly have already shown relatively good results. However, it is necessary, on this foundation, to develop recognition systems aimed at those for use with multiple persons, large amounts of vocabulary, and words and phrases presented in continuous series. By the same token, this is easier said than done. There are people who point out that when the design plans for special purpose recogntion systems are put into use in test manufactured recognition systems, the price is not very great, and fixing a design plan for a system that has already been put to use is also not the same thing as redesigning a system that is in use. As far as recognition systems for large amounts of vocabulary are concerned, they are primarily in the processes of raising recognition capabilities and simplifying learning. When speaking in terms of recognizing vocabulary that is presented in sequence, words and phrases are a decided problem. There are people who advocate opting for methods involving the dynamic forming of rules, time matching methods, and other similar abilities in order to raise the precision of separations. There are also people who promote a linking up with language comprehension, making use of the meaning of language and grammatical knowledge to raise the degree of the precision of the recognition.

Complete language recognition systems should be a crystallization of comprehensive operations related to a number of fields of study such as thought or cognition, biology, information, language, and other similar fields, as well as various types of knowledge and skills. At the current stage, the test manufacture of language comprehension systems is only capable of taking the test manufacture of language recognition systems as a foundation. In the stage of selecting language sounds as well as words and phrases to recognize, it is possible to borrow for use results of research which already exist. In the stage of forming terms and phrases and testing sentences, it is necessary to use grammatical rules and semantic distinctions. In order to raise the degree of accuracy in comprehension a step further, one should also add, in addition, sound pattern or rule displays and analyses of language usage. Taking statistical form recognition and grammatical form recognition and putting them together is also an important measure to take. On the foundation of machines carrying out automatic recognition and comprehension, one must add artificial measures for intervention and correction. This is to take the level at the present time, in systems for the comprehension of language, and put into practice a practical type of compromise or eclectic design.

The pronunciation organs in human beings are constantly changing. As a result of this, the sounds of people also have no precise, fixed form. They do not resemble peoples fingerprints or that unchanging sort of thing. This is particularly the case in situations in which sounds are disguised. The range of changes in the forms of the sounds of language, as reflected in the characteristics of individual speakers, are even larger. These several disadvantageous factors limit the raising of the rate of recognition of systems for the recognizing of persons doing the speaking and the results of practical applications. However, the physiological changes in the pronouncing organs are a process of gradual alteration. It is possible to opt for the use of constantly updated standard holotypes of the sounds of language and for making use of large amounts of language sound samples in order to carry out statistical averaging type methods for producing improvement. Moreover, the camoflaging of the sounds of pronunciation is a process of sudden change. The parameters for the sounds of the language change violently. One should, from the various physiological, physical, and psychological changes in such aspects of the speaker's voice when camoflaged, carry out on it theoretical analyses and experimental research, finding out the patterns of change in the parameters of the sounds of the language when the pronunciation is disguised, and opting for the use of those several speech sound parameters which are not sensitive to camoflaging of the pronunciation to form characteristic vector quantities for recognizing speakers voices.

V. CONCLUSIONS

This article, from the angles of information processing and bionic functions, has roughly introduced research on natural hearing and the development of artificial hearing. Obviously, the core question with relation to hearing, that is, the brain's comprehensive processing function on hearing information and its artificial bionics, at the present time, has shown research results which are only capable of being called very preliminary. Relatively perfected artificial hearing systems should basically possess hearing functions imitating those between people. However, this is not an objective which can be reached within a short period. Moreover, it is necessary to make cooperative use of numerous knowledge disciplines as well as long term struggle. Only then will it be possible to complete the task. In the current stage, it would do no harm to take a number of relatively advanced artificial hearing systems and add to them, under conditions of artificial intervention, the carrying out of applications or test utilizations. At the same time, one should also continue to exert maximum strength on theoretical research and technological development, in order to bring about constant perfecting of the operating properties of artificial hearing systems.

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